The Prediction of Chaotic Time Series Using Neural Networks

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Abstract: Neural networks are powerful tools of prediction and classification. The capabilities to predict chaotic time series are once more emphasized in this paper, by showing the results obtained in the case of prediction the share trades value at the Bucharest Stock Exchange. The paper presents the main notions used in chaos theory, the main steps to follow when building a neural network model and finally the results obtained.

Keywords: chaos, neural networks, chaotic time series, prediction.

1 Introduction

Generally speaking the behavior of a chaotic system is completely determined by its past behavior, but practically any slightest change in initial condition determines a completely different and sometimes unpredictable evolution of the system.

The chaotic processes are not random but repeat the same characteristics in the state phase.

In the majority of the processes (some of them improperly called random) there is a tight and subtle intercommunion among causes and effects, being so many causes and the global image created by the multitude of these causes (insufficiently known) being so large that the strict determination cause-effect is extremely difficult to made and almost impossible. The most popular example and most quoted in literature referring to the cause-effect interconnection is the Ed Lorentz example – "the butterfly effect": the flapping of the wings of a butterfly in an Amazonian forest can cause as a consequence of a cause – effect long chain the occurrence of a storm in Texas.

Theoretically any process that evolves in time can develop a chaotic behavior. It's been studied the chaos in the following fields: the spreading of epidemics, the forest fire spreading, the economic changes, the evolution of certain fish or insect species, etc.

Chaos occurs in dynamic nonlinear deterministic systems. The causes that determine the occurrence of chaos are not fully known. There are three possible causes identified:

- the growth of control factor to a high value
- the nonlinear interaction of two or many physical operations (the double pendulum)
- the effect of noise presence.

A chaotic system (process) is highly sensitive to the variations of the parameters describing the initial state. For example any change of the initial conditions (the atmospherically conditions of today) will cause o major change of the tomorrow atmospherically conditions, the initial change having a major influence in three day weather forecast. In this case the impossibility of knowing the initial conditions and the sensitivity of the system determines that the long term prediction to be impossible despite the fact that the system is deterministic and the laws of physics are exactly known.

A chaotic process (system) implies the following paradox: is initially generated in a deterministic dynamical system yet its evolution in time is apparently random. [1]

Chaos can be:

- deterministic - the behavior of the system can be exactly represented by means of a mathematical function or an heuristical function. The evolution of such a system, although governed by fixed rules, can present a behavior such complicated that can seem random.
- nondeterministic – the behavior of the system can't be represented by a deterministic function causing the system to be totally unpredictable.

Concluding, one can say that a chaotic system will embed the following features:

- sensitivity to the initial conditions:
- a chaotic process or system passes through areas or points in the phase space called chaotic attractors by not repeating the same trajectory. A chaotic system can have in the state phase one or more chaotic attractors towards the system evolves.
- expansions and contractions in the phase state. A dimension in the phase state is characterized by a value called the Lyapunov exponent. A chaotic process will have at list one positive Lyapunov exponent (L). Its magnitude versus time indicates the starting moment from which the process becomes chaotic. A negative Lyapunov exponent indicates how rapidly the system restores its initial state after a perturbation.

- the presence of an attractor towards the system converges can offer an image of its future evolution.

2 Artificial Neural Networks (ANN)

As tools for prediction were used (and the examples from the literature demonstrates the large scale use of these artificial intelligence techniques) data mining techniques and algorithms, genetic algorithms, neural networks and fuzzy logic or combinations of these tools each with its own advantages and disadvantages.

A neural network is a mathematical model relying on the model of the biological neurons. A neural networks can acquire knowledge from the environment through a learning process and the interneuron connection strength (the weight) is used to store the knowledge. In fact a neural network learns by adapting continuously the weight until a performance criteria is satisfied.

Artificial Neural Networks offer qualitative methods for business and economic systems that traditional quantitative tools in statistics and econometrics cannot quantify due to the complexity in translating the systems into precise mathematical functions.

As classical applications of neural networks can be mentioned:

- mortgage risk assessment
- financial and economic forecasting
- detection of regularities in security price movement
- prediction of bankruptcy
- predicting the investor's behavior
- time series analysis and prediction, etc.

The traditional statistical analysis requires specifying the precise relationship between inputs and outputs and any restrictions that may be implied by theory [3]. ANNs differ from conventional techniques in that the analyst is not required to specify the nature of the relationships involved; the analyst simply identifies the inputs and the outputs. No knowledge of ANNs training methods such as back-propagation is required to use ANNs. In addition, the ANNs' main strength lies in its ability to vary in complexity, from a simple parametric model to a highly flexible, nonparametric model.

In order to build a model for prediction there are some steps to follow [4]:

- the parameters that influences the value to be predicted need to be identified

- the input data set is collected (the evolution of the inputs in time, i.e. the time series of the inputs); the data set needs to be redundant (sufficiently large hundreds or thousands of forms). If there is necessary the input data set is normalized (all values are of the same order of magnitude). The normalization can be performed using the following formula:

$$x_{new} = \frac{x_{old} - x_{\min}}{x_{\max} - x_{\min}} \quad (1)$$

or

$$x_{new} = \frac{x_{old} - x_{mean}}{x_{\max}} \quad (2)$$

- the data set is presented at the inputs and the output data set at the outputs and the neural networks begins to learn
- after the completion of the learning algorithm, the assessment of the relevance of the inputs is carried out.
- the inputs with no influence are eliminated from the input data set and the network retrained.
- the parameters of neural network (number of hidden layers, the number of neurons from each hidden layer, the momentum, the learning rate, the initial weights) are readjusted
- the process of building a model for prediction using neural network is "trial and error".

The performance criteria, which once satisfied stops the learning algorithm must be carefully chosen. If an ANN is over trained, a curve-fitting problem may occur whereby the ANN starts to fit itself to the training set instead of creating a generalized model. This typically results in poor predictions of the test and validation data set. On the other hand, if the ANN is not trained for long enough, it may settle at a local minimum, rather than the global minimum solution. This typically generates a suboptimal model.

In that follows the practical result for the problem chosen – the prediction of the shares trading at the Bucharest stock exchange – are presented.

The input data set contains 260 forms and is available on the Bucharest Stock Exchange site [2]. The neural network used is a RBF neural network with (initially) 7 inputs and one output (the value to be predicted). The results obtained are shown in Figure1.

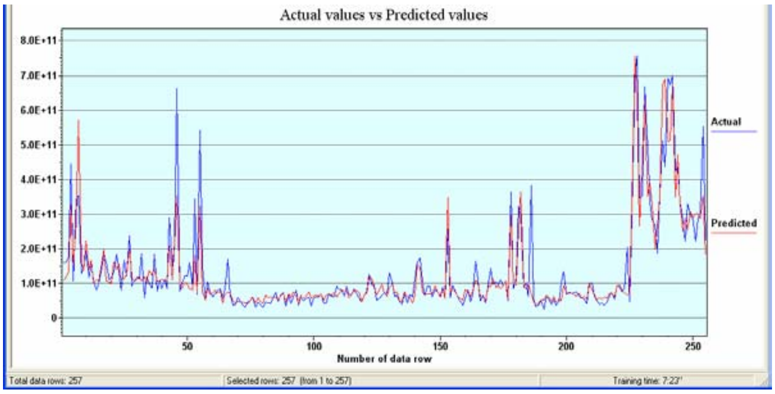

Figure 1
The results predicted output versus desired output graph

The inputs relevance is evaluated and 2 of the inputs are eliminated from the input data set. There ANN will have 5 inputs.

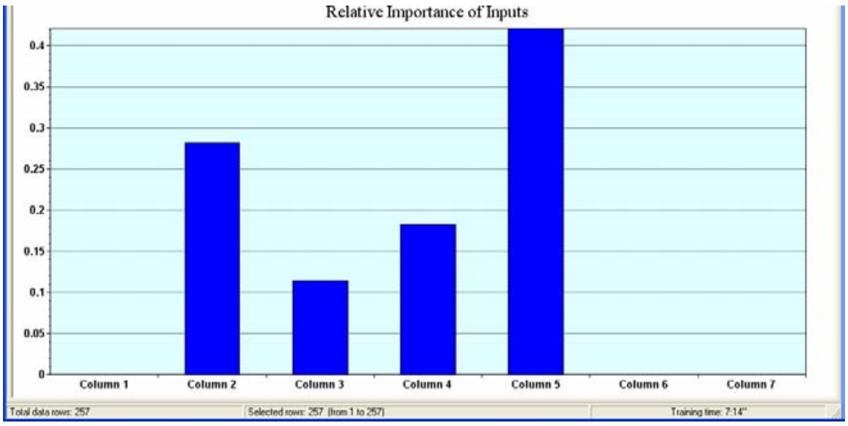

Figure 2
The relative importance of the inputs

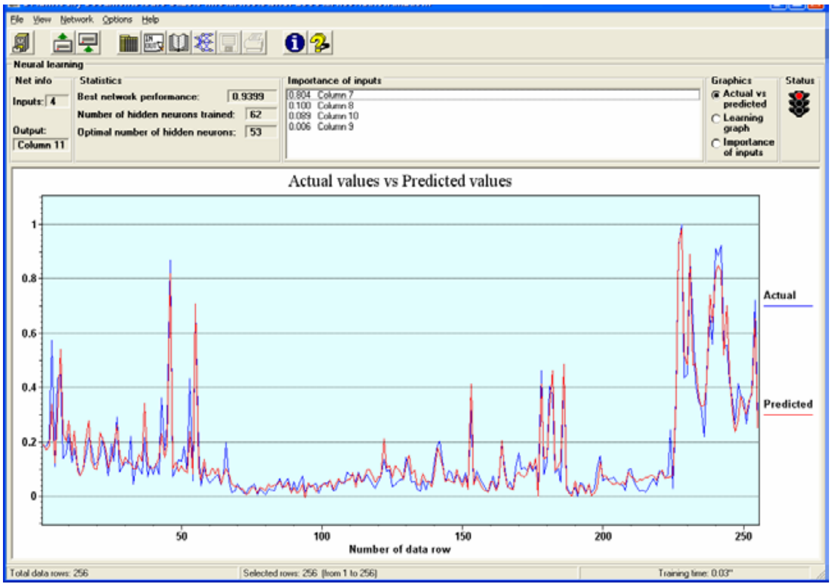

Figure 3

Neural network result after learning the input data set (normalized data)

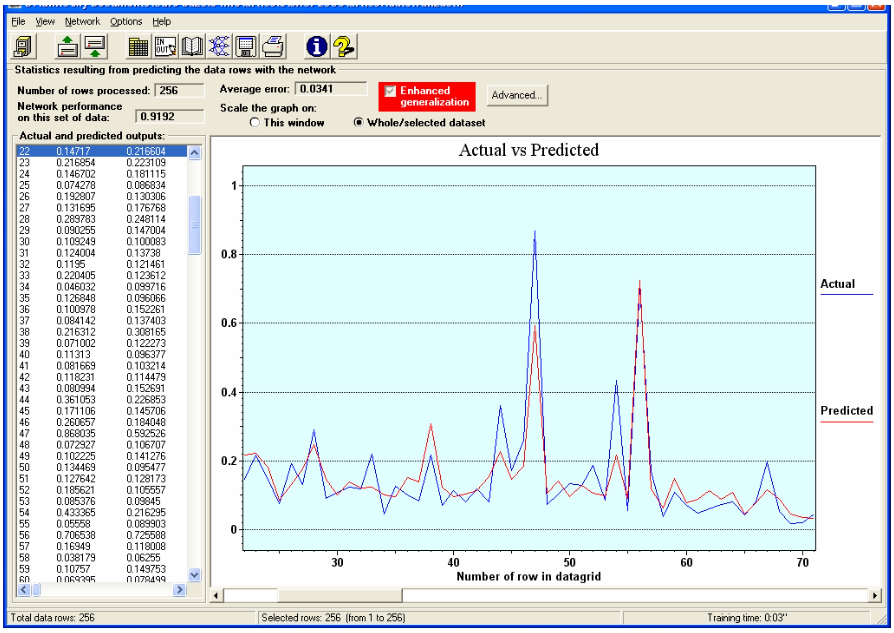

Figure 4

Predicted versus actual values of the output for 70 input forms

Conclusions

The quality and accuracy of the prediction relies on many factors. Neural networks can predict chaotic time series, the process of building being an elaborate process with a trial and error character. The results of the prediction can be refined furthermore by training the network, changing its parameters or changing the network type.

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